The Water Supply in Ships From Its Beginning to the Present Time.

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Reprinted from the Journal of the American Medical Association, December 16, 1905.

CHICAGO:
PRESS OF THE AMERICAN MEDICAL ASSOCIATION,
ONE HUNDRED AND THREE DEARBORN AVENUE,
1906.

THE WATER SUPPLY IN SHIPS FROM ITS BEGINNING TO THE PRESENT TIME.*

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The problem of the water supply for sea-going ships is one of the most important and, at the same time, one of the most difficult to solve of all the problems of naval hygiene. It certainly is not a simple question. Ships can not always choose the source of their water supply. It may be impure or even infected to begin with. But even granting that it was faultless when collected, it may not remain wholesome during a long cruise.

The early efforts of the old sanitarians to provide faultless drinking water for seamen are full of pathos. Before the last century men did not know in what wholesome drinking water consisted. Much less did they know how to preserve it pure and sweet. When in addition to the ignorance of the age we find all efforts toward progress met either with cold indifference or active opposition, we may easily see why so little advance was made and feel a deep sympathy with the old ship's surgeons, Blane, Lind, Trotter, Fonssagrieves and many others in their fight against such obstacles.

To-day, with the help of chemistry and biology, the naval hygienist has come nearer solving the problem of a perfect water supply. While there are yet a few details to be perfected, we feel that they will soon be remedied and we, therefore look to the future with confident hope of success.

SOURCES AND COLLECTION OF WATER.

Until recently little or nothing was known about what drinking water should or should not contain. Of

* Read in the Section on Hygiene and Sanitary Science of the American Medical Association, at the Fifty-sixth Annual Session, July, 1905.

the two classes of impurities, organic and inorganic, the inorganic was the first to be investigated. About 1850 chemistry was far enough advanced to come to our aid and give us a few analyses of water. Later in the century biology helped us to discover the source of the more dangerous form of organic contamination and gave us means and methods for preventing the same.

A century ago, however, nothing of all this was known. The old sanitarians were influenced in the choice of water not by knowledge but by personal whims, a condition which even to-day has not wholly passed away. Neither chemistry nor biology has given us analyses that can be considered as generally applicable to all places and conditions at the same time. Different localities on the earth's surface produce waters of different compositions, and neither a chemical nor a biologic examination of a given water may be of any great value without a local inspection of its source. When we, moreover, consider that it is the proper and judicious interpretation of all the data involved that can give us an adequate idea of the nature of a water, we ought rather to be surprised at what the old sanitarians did know than at what they did not know.

Dr. Gilbert Blane,[1] for instance, tells us that "spring water is to be preferred to running or stagnant water," saying "unless it is taken at the source or near it, it is apt to be impregnated with decayed animal and vegetable substances, such as grass, wood and dead insects. This is an inconvenience that is greatest in hot climates, where everything teems with life and where materials of putrefaction are both more abundant and more prone to corruption."

That the greatest danger was hidden in the organic impurities of water was already well known in the middle of the eighteenth century, at least to Blane, we have a right to infer, for he says of that kind of impurity that "it is the most pernicious impurity" and that "the mineral impregnations common in springs are seldom in any degree unwholesome and do not, like the other, make the water corrupt." These are certainly correct observations and would pass muster to-day. The great and urgent necessity in those early times of navigation to procure a good and wholesome drinking water for a

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1. "Observations on Dis. of Seamen," 3rd Edition, London, 1799. p. 297.

ship, in most any part of the world, sometimes took those old sanitarians far afield to inspect any lake, brook, spring or well that offered such a supply and made them practically acquainted with the natural sources of water the world over.

That meteoric water was at least in part depended on for furnishing a supply of drinking water, is perhaps easily understood, and may, moreover, be gathered from the early writers. Thus, Captain Cook, during his memorable cruise between 1772 and 1775, during which it is said that he lost but one man from disease, attributes to rainwater the swelling of the glands of the throat, and Gautier says of glacier water that it is very unhealthy. But Saussure already has called attention to the fact that the people in the high Alps, as well as the Esquimos, known to consume water from melted ice and snow, were essentially healthy peoples; and Wilson[2] says of rainwater : "When carefully collected, kept for a week or two in an iron or brickwork cistern, until its organic matters are decomposed, there is probably no better drinking water to be obtained." The explanation of all this is, as we know now, that rainwater, especially when collected in mid-ocean, is essentially a distilled water. While free from positive contamination, it never contains mineral salts to make it palatable.

One danger not sufficiently recognized in the early days of navigation is becoming better appreciated in recent years. That is the danger from contamination of water during its transport from shore to ship. A water perfectly pure and wholesome at its source may, by the time it reaches the ship or the sailor's stomach, be totally the reverse. Water, no matter from what source, must be taken to the large ships by a water boat. Barrels, wooden or iron tanks, earthenware vessels or even open rowboats may intervene between the natural source of supply and the scuttle-butt, with all the chances of contamination which such transport suggests. It is useless to say that, in these days of distilled water, these methods are no longer in practice. Every naval surgeon knows that a cruising ship will often take water from shore and fill its tanks with it, whether it is merely feed water for the boilers or not. These same tanks

2. "Naval Hygiene," by Joseph Wilson, M.D., U. S. Navy, Philadelphia, 1879.

are used again for drinking water and consequently can remain safe from infection only when none but pure water is allowed to be stored in them. Again, every cruising ship will now and then get into places in which the most primitive methods of watering a ship are the only resource.

The usual method of examining water after it had reached the side of a ship in a water boat was merely perfunctory and of no practical value whatever. A sample of it was indifferently collected in a tumbler or tin vessel by a messenger boy and sent to the apothecary for examination. The only test applied was the nitrate of silver test for chlorids and the water was pronounced good or bad in proportion to the turbidity being much or little. Better training of naval surgeons in methods of hygienic water analyses and a more liberal supply with the means to carry them out on board ship have wrought great changes and improvements within recent years. But unless the naval sanitarian watches every step which the water takes from its source of collection until it finally reaches the tanks of his ship, he can form no adequate idea and make no trustworthy report as regards the quality of the water collected. No chemical or bacteriologic examination will give him data sufficient to make a complete and sufficiently reliable report on the quality and fitness of the water in the ship.

STORAGE OF WATER.

The storage of water on board ship dates from the time when ships first took to the high seas and went out on long voyages away from land. For short voyages in small boats little water was needed and the time of storage was short. This small amount was kept in earthenware vessels, and even to-day this is the favorite and handy means of keeping small amounts.

For long voyages, however, where the crews are large, this method is inadequate and wooden barrels at first took the place of earthenware jars. Notwithstanding the fact that water thus stored became putrid after a while, this antiquated method of storing endured over 200 years. Putrefaction was expected to occur as a matter of course and was so universal on shipboard that sailors had the common superstition that water had to putrefy three times before it became drinkable. No one ever succeeded in preventing this putrefaction of water stored in wooden casks or barrels.

That the wood of the barrels out of which the casks were made had something to do with putrefaction of the water stored in them was well known to the old, observing sanitarians, who had various ways of treating these casks so as to preserve the water in good condition. Says Blane,[1] "The purest water is apt to spoil by producing a putrid glare on the inner surface of the cask which contains it. There is a great difference in this respect between a new cask, especially if made of moist wood, and that cask which has been hardened and seasoned by age and use. Several contrivances have been proposed for preparing casks that hold water, but none have been found by experience so effectual as letting them stand for some time full of sea water, and it is a great advantage of this method that it is so easily practicable." And then he continues to say: "We consider all water kept in wooden vessels as more or less liable to putrefaction, but there is a substance which is neither rare nor costly that effectually preserves it sweet. This is quicklime, with which every ship should be provided in order to put a pint of it into each butt when it is filled."

"It is probably owing to the small amount of quicklime found in Bristol water that it is so incorruptible. It has the advantage of not being injurious to health but, on the contrary, is rather friendly to the bowels, tending to prevent fluxes." Finally, he fortifies his recommendations by experience, saying: "In the year 1779 several ships of the line arrived in the West Indies from England, and they were all afflicted with the flux except the *Stirling Castle,* which was the only ship in which quicklime was put into the water."

Blane explains the action of quicklime by the destructive property which it has on animal life and on the "glare" that collects on the sides of the cask, as much as on a species of vegetation of the order called algæ by the naturalist. He also speaks of alum, cream of tartar, vinegar, vegetable and fruit juices and tamarinds as having been made use of. He relates, among others, that the fleet under Sir Charles Saunders found that the waters of the St. Lawrence produced fluxes and that this quality was removed by throwing in four pounds of burnt biscuits into each cask before it was used. But he adds, "there is nothing so effectual and subject to so

few inconveniences as quicklime." Thomas Trotter,[3] after treating on diet, remarks: "We can not leave the dietetic part of our work without adding some remarks on water. We were employed the whole summer of 1792 in making experiments on the best method of preserving water pure and sweet in long voyages, and a summary of this is published in a later work called 'Medical and Chemical Essays,' printed by Jordan, Fleet street, for Mr. Maubray of Portsmouth, to whom I presented a copy at the time his printing office and materials were burned, in December, 1794. We found, after trying everything, that the best practicable method was gently charring the casks in putting them together, both staves and heads, which rendered the surface unfit to decompose the water. But so little was this practice deemed perfect by the victualling board that Mr. Reeks, the cooper at Weevil, showed us an order from the commissioners expressly forbidding it, as they said it blackened the fluid." Then he continues: "It, moreover, makes the casks last longer by hardening them against worms in hot countries and also less liable to shrink from the hoops.. The whole process," he says, "is dependent on chemical principles in the above work and no one has dared to say that they are wrong." "I now, in the name of the service, request some captains to take the business up and carry to sea a given number of casks filled with pure water, one-half charred according to our way and the other half in the common way. Some trusty person must superintend the duty that it may be fairly tried, for we know it must succeed."

PRESERVATION OF WATER.

Nowadays, none but a few fishermen perhaps use the wooden casks for water. Since we can not and will not wait for our water to become thrice corrupt, as the old saying was, some shorter means had to be found. It was becoming more and more recognized that the method of storage had to be improved in order to preserve water sweet. The otherwise good effects of charring having proved of merely temporary benefit, sulphurization was tried and found better. The manner after which sulphur was used is as follows: The sulphur was burned in the barrel and then the barrel was filled one-fourth of its capacity with water, then some more sulphur was

3. Trotter, Thomas, M.D.: Medicina Nautica, London, 1804, vol. II. p. 167.

burned and the barrel filled half full of water, and so on until the barrel was full. Then, for every ten liters of water twenty drops of sulphuric acid was added and the barrel covered up. Such water, though with an acid taste, was not disagreeable to drink.[4] Then the addition of oxid of manganese was attempted in the proportion of one gram to 150 liters, as had been recommended by Perrinet. Although this process gave the water an acrid, rather astringent taste, it was inoffensive, more expeditious and much easier carried out than sulphurization. In 1822 four barrels of water were treated in France, two by charring and two by addition of oxid of manganese. After 33 months the water in the former two was found to be in a putrefying condition and that in the latter two was found good to drink in spite of its taste. The facts could not be denied and every one

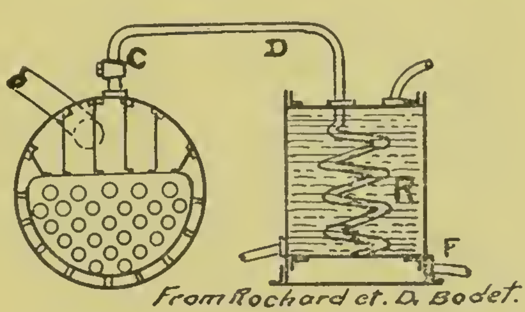

Fig. 1.—Distilling apparatus of Rochard and Bodet.

had by this time come to recognize that all efforts to render wooden barrels a fit means for water storage had miserably failed in one way or another. Recommendations for substituting iron casks for wooden barrels were first made as early as 1739 by Sibon, a captain at the port of Toulon,[5] while General Bentham is said actually to have introduced iron casks into the British navy in 1798, after previously experimenting with them for years. This was done later also in the French navy, and the cruiser *Uranie,* fitted out to go on a scientific expedition, was the first ship of the French navy supplied with iron tanks alone.

This does not mean, however, that the practice became universal immediately. On the contrary, it spread very slowly, indeed, for we have in our own navy a fairly

4. Rochard and Bodet: "Traité d'Hygiene Navale," etc., Paris, 1896, p. 405.
5. Lefevre: These de Paris, 1869.

recent record of the use of wooden casks down to the latter part of the last century. Rear Admiral G. W. Baird,[6] U. S. N. (retired), writes me that the sailing sloop *Constellation*, of 1,186 tons displacement, carrying a crew of 228 men, had 48 iron tanks and 124 wooden casks, containing 32,364 gallons, 120 tons of water. The amount of space which these water casks occupied is shown in the further statement of Baird, when he says: "The 48 iron tanks alone weighed 31 tons, there being no record of the weight of the casks. In this ship it will be seen that a little over one-eighth of her total displacement was taken up in the water supply." The delay in the introduction of iron tanks must be attributed to two principal causes: (1) In prebacterial days no satisfactory explanation could be given for the occurrence of putrefaction in wooden barrels, and therefore no good reasons seemed to exist why the same water should not putrefy in iron casks as well as in wooden vessels. It was not recognized and, consequently incredible that the source of putrefaction consisted in bacterial action on sulphates contained in the water. Now that we know of sulphur bacteria engaged, on the one hand, in reducing sulphates to sulphuretted hydrogen, and in oxidizing the latter to sulphates, on the other, we can better understand at least one of the causes of this trouble and how the porous wooden walls became the culture plates for that class of organisms. (2) The other reason is that iron casks, although a great improvement over wooden barrels, also had their serious objections themselves. One of these was that they were expensive and the other was that the iron was quickly oxidized and the resulting rust deposited in large quantities. The iron rust that forms as a result of the direct contact of pure water with the unprotected iron plates is at first deposited: when the ship gets under way it becomes suspended in the water. When we add to this the heat of a tropical climate and of a hot ship, a drink of such water, it may easily be imagined, is not very refreshing, to say the least of it.

According to Rochard et Bodet,[4] from 8 to 10 kg. a year were collected from a single tank.

Since it was, moreover, not indifferent for the health of the consumers whether a water did contain iron rust or not, means had to be taken to prevent the water from

6. Letter: See also Journal Franklin Institute for 1872.

coming in direct contact with the iron, thus keeping the tank from being eaten up and the rust from getting into the water. After experimenting with various kinds of gums and gum resins, with lead and zinc linings and coating the walls with lime in more modern times, the most commonly employed material to-day and the least objectionable for lining these tanks is Portland cement.

In lining the tanks with cement, various additions to the latter have been recommended. Thus, Sestini recommended that chalk be added to it; but this resulted in a very hard water. The best and simplest process is that recommended by Lefèvre and is as follows: The sides of the tank are thoroughly scraped with a metallic brush to free them from rust. This is followed by flaming the sides with a soldering lamp. After flaming, the best Portland cement, made into a convenient consist-

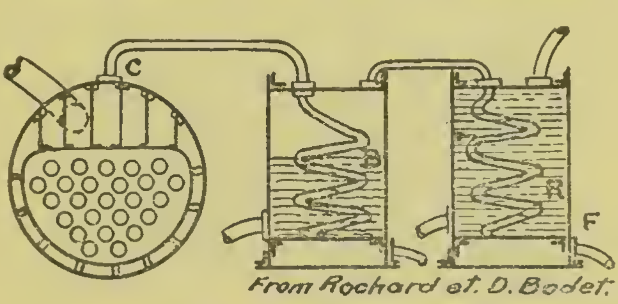

Fig. 2.—Distilling apparatus showing special condenser.

ency, and prepared with boiled water, is applied with a soft brush and allowed to set perfectly; several coats may be applied if necessary. After the cement has hardened, the tank is ready for use. Such a lining, it is claimed, will last for two years. Chalk, to say the least, is unnecessary. We may conclude, therefore, that the problem of preserving water on board ship is provisionally solved and that iron tanks with a cement lining will be used in the future on all ships of the navy as in those of the merchant marine where the vast importance of a good, wholesome water is recognized and appreciated.

WATER CORRECTIVES.

Imagine seamen in the early days of circumnavigation, far away from land and pure water with nothing but bad water to quench an ever-recurring thirst. We cannot wonder that they should try by every means conceivable and inconceivable to improve their drinking

water. We, therefore, find a host of remedies for bad water some of which even anticipated the methods in use to-day. Says Blane, writing in the latter part of the 18th century: "When the water of wells or brooks is found loaded with mud, the following expeditious method of filtration, described by Dr. Lind, has been practiced with success: 'Let a quantity of clear sand or gravel be put into a barrel placed on one end without the head so as to fill one-half or more of it and let another barrel, with both ends knocked out, of a much smaller size, be placed erect in the middle of it and almost filled with sand or gravel. If the impure water be poured into the small barrel or cylinder, it will rise up through the sand of the larger one in the interval between it and the small one.'" In this description, we can see, without a great stretch of the imagination, the

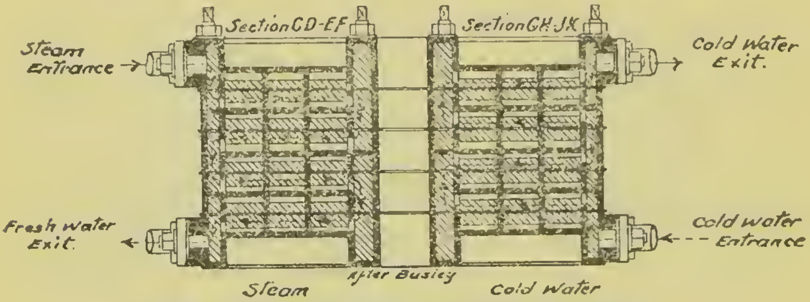

Fig. 3.—Pape and Henneberg condensor.

germs of the construction of a modern well or of the present method of sand filtration, if not of the Pasteur-Chamberland candle. Again, with regard to aëration, Blane says: "Such is the attraction of the air for this offensive matter that the water need only be brought thoroughly in contact with it to be rendered quite sweet." Then he describes an apparatus invented by a Lieutenant Osbridge. With this apparatus the water in the cask was raised a few feet and allowed to fall through several sheets of tin plates perforated like "colanders" and placed horizontally. Blane speaks of it as "a machine very deservedly in common use and the working of it is a modern and salutary exercise to men in fair weather." Thus we may take it for granted that, besides filtration, these old sea sanitarians knew well the effects of aëration as far back as 1750.

At that time the water they had to deal with was presumably full of decaying organic matter. These old

wooden casks were indeed nothing more nor less than what we now conceive to be septic tanks and in the conditions under which these tanks were kept, down in the bottom of the ship, dark, damp and mouldy places, poorly, if at all, ventilated, the anaërobes must have led an ideal existence. Consequently, aëration produced an improvement almost startling.

DISTILLATION OF WATER.

Among all the numerous water correctives, distillation requires a special treatment, on account of the large and important part which it always played in connection with the water supply on shipboard. It is now well recognized that at least one of the reasons why distilling of sea water did not become more quickly popular than it did, was the firm belief entertained at that time—and still entertained by some of the present day—although for better reasons than of old, that something had to be added to it before distilling was begun, so as to "remove the spirit of salt." It was perfectly well known to Dr. Lind and to his sympathizing contemporaries, however, that the distilling could be done without adding anything to the sea water to begin with. Says Lind:[7] "In 1761, I had publicly demonstrated by various experiments at the Royal Academy at Portsmouth, that a simple distillation rendered sea water perfectly fresh, pure and wholesome. These experiments were made in the presence of Mr. Hughes, resident commissioner of the navy at that port, and of Mr. Robertson, late master of that academy. In the month of May, 1762, an account of this discovery was read at a numerous meeting of the Royal Society in London; in March, 1763, the second edition of my essay on preserving seamen, containing this discovery, was published in London, by the authority of the Lords Commissioners of the Admiralty; which honor their lordships were pleased to confer on account of this important discovery."

Hauton, in 1670, is said to have recommended caustic alkali for the purpose of destroying the bituminous matter. Appleby, in 1734, published his procedure by order of the English admiralty, in which he extolled the virtues of caustics and calcined bones. Butler employed soapsuds. Walcot added antimonial preparations, while

7. An essay on diseases incident to Europeans in hot climates. Philadelphia, 1811, p. 242.

still others wanted to let the water putrefy before beginning its distillation. Lastly, Perrinet, in more recent times proposed the addition of manganese and charcoal in the proportion of 1:5000.

While, then, the credit of having been the first to suggest and to carry out distillation of pure water from sea water is claimed by several individuals, it may be said that distilling did not come into general use before 1761, when Dr. Lind was fortunate enough to discover that sea water simply distilled, without the addition of any ingredient, afforded a water as pure and wholesome as that obtained from the best springs.

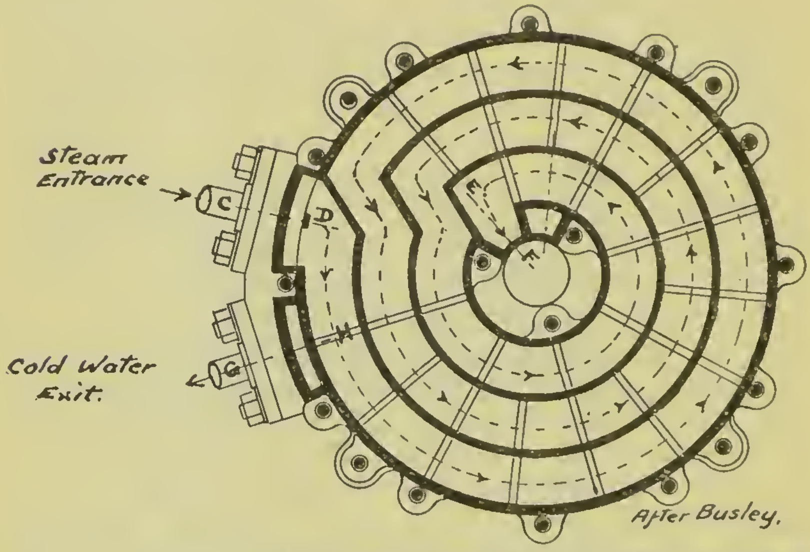

Fig. 4.—Pape and Henneberg apparatus, showing tubular arrangement of condenser.

Even the discovery of the learned Dr. Stephen Hales[8] did not find general favor at that time, although received with considerable enthusiasm by some; so that, distilling may be said to have begun in earnest from the time when Dr. Lind's discovery became generally known. The earliest attempts at distillation were clearly not successful. According to Lefèvre[5] it was Gauthier of Nantes who constructed a distilling apparatus as early as 1717 and Dove and Hoffmann constructed one in 1765. Both these were rejected on account of being too cumbersome. The rudest kind of contrivances were at first

8. Stephen Hales, D.D., F.R.S.: "An Account of a Useful Discovery to Distill Double the Usual quantity of Seawater by Blowing Showers of Air up Through the Distilling Liquor." London, 1756.

devised. The stills in Blane's time, employed on English ships, are described as consisting merely of a "head and worm" adapted to the common boiler, and in which distilling was done, while the food was being cooked. More than eight gallons of excellent fresh water were said to have come off in one hour from the copper of the smallest ship of war.

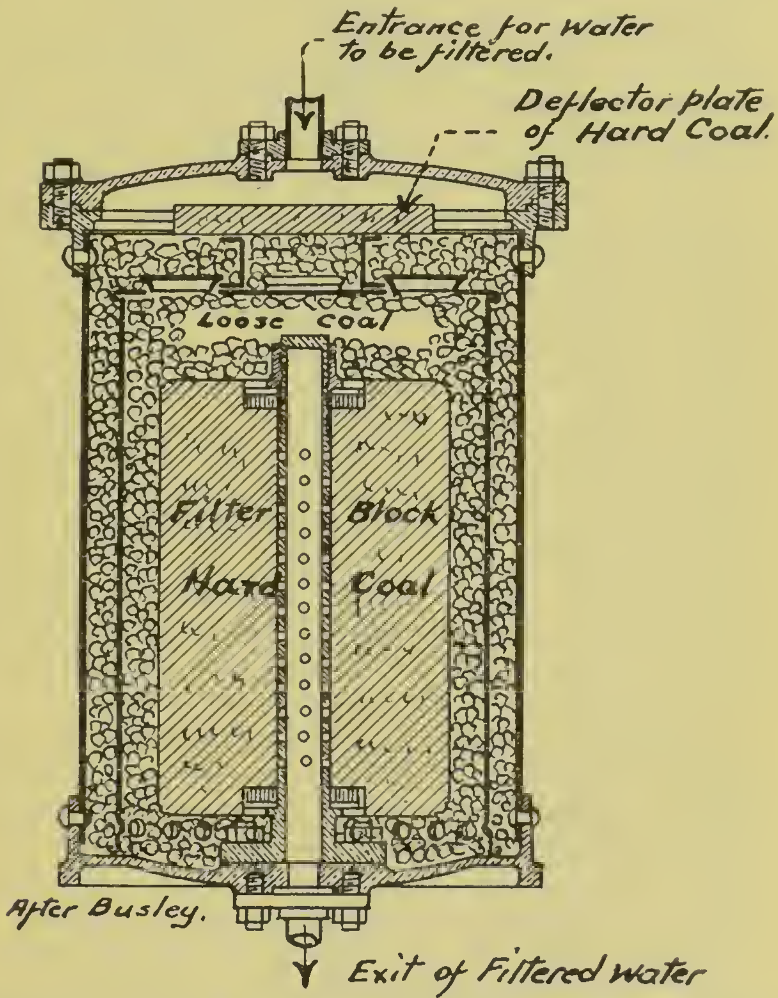

Fig. 5.—A filter of the best pattern showing how the water enters and is at once deflected by a carbon plate over loose pieces of carbon.

An extemporized distiller by Dr. Lind is described as consisting of a tea kettle with the handle taken off, and inverted on the boiler, with a gun barrel adapted to the spout, passing through a barrel of water by way of "refrigeratory" or kept constantly moist with a mop. In 1763, Dr. Poissonier devised a distiller that could

be adapted to the ship's kitchen and about the same time Irving in England devised a similar apparatus, both of which were received with great enthusiasm at the time.

The progress which the introduction of distillers made in the early part of the 19th century was destined to receive one more brief check. In 1817, Sage, in an impressive memoir, strongly protested against the general introduction of the distillers of Poissonier and Desormes into ships, claiming that distilled water was dangerous and demanding that new experiments be made before installing these distillers. To judge by what followed the publication of this memoir, it must have made a deep and widespread impression; it also indicates the general importance attached to the whole subject at the time. A series of experiments were at once begun on convicts. Water from the ports of Brest, Toulon and Rochefort was distilled and 41 convicts made to drink none but distilled water for a whole month. Behold! their health was found not to suffer in the least as a consequence of the water they drank. A captain and several other commissioned officers drank of the same water without injury to their health. After these experiments, the question raised by Mr. Sage of the existence of a poisonous "alkalino-oleagino-neptunien gas," according to Lefèvre, was finally decided against him. The end of this controversy was likewise the beginning of improved distillers for use in ships.

The distilling kettles consisted of quadrangular cases made of sheet iron, their interior being divided into three compartments by two horizontal partitions. The lower compartment was the hearth or furnace, the middle compartment contained the sea water to be boiled and distilled and the upper compartment was the place where the food was cooked by the steam generated below. Such a distilling kettle was surrounded on the sides by refrigerators through which ran a spiral pipe in which the steam was condensed.

It is easily seen that the quantity of water furnished by these distilling kitchens was small and barely gave the amount of water necessary for drinking purposes. The demand for larger quantities was soon supplied by larger as well as better distillers. How slow their general introduction was, into the U. S. Navy in particular, is best shown in the letter from Admiral Baird, already

referred to, as well as in the account of an improved distilling apparatus given by him in the *Journal of the Franklin Institute* for 1870 and 1872. The first serious

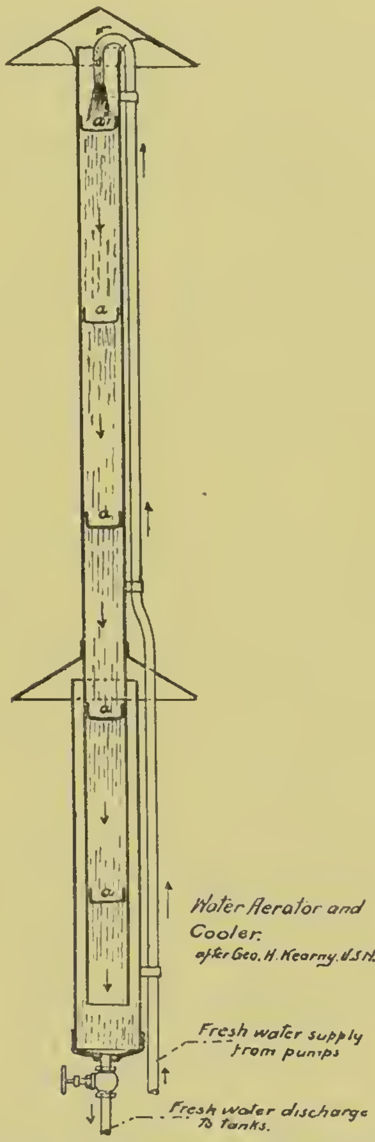

Fig. 6.—Showing aërator constructed by Capt. G. H. Kearney, U. S. N.

attempt in the construction of distillers for use in the U. S. Navy was begun by him in 1866 on the *Pensacola,* and in 1877-8, I made a cruise on a sloop of war under sail from San Francisco around Cape Horn to Washington, a journey of 112 days, without a distiller of any kind on board.

For a long time, it was steam from the main boilers that was condensed to furnish potable water. The arrangement was of the simplest kind. One of these boilers was tapped and the steam escaping through a spiral copper pipe was cooled to condensation as may be seen illustrated in principle in Fig. 1. Such water, as might be expected, was almost invariably laden with all the impurities, not only of the sea water, but also with those from the inside of the boiler itself, especially fatty acids, which imparted to the water its well known empyreumatic odor.

Special distillers of greatly improved pattern were made during the latter part of the last century. The most notable among these were the Cousin, the Weis and the Mouraille in France, the Normandy, in England, the Standard Evaporator in the United States and the Pape and Henneberg in Germany. The general principles in the construction of them all is as follows: The sea water is conducted into a special reservoir where it is heated by steam pipes connected with one of the boilers from the main engines. The steam in this arrangement does not mix with the salt water to be evaporated, providing everything is tight, but, after heating the sea water which surrounds these pipes, returns to the main boiler whence it came. The evaporated sea water is condensed in a special apparatus called the condenser (Fig. 2).

Since all the most essential changes and improvements in the present distillers have occurred in that part of it known as the condensor, I may here limit myself to describing what is at present believed to be the best and most economical one in use, namely, the one designed by Pape and Henneberg of Hamburg, Germany.

The Pape and Henneberg condenser (Figs. 3 and 4) consists in a number of flat elements, each one of which is divided into two by a central partition on each side of which the spaces are arranged spirally. The cold water entered from below runs from the circumference to the center of the lower spiral chamber of the lowest element. Thence it rises through an opening in the separating plate up into the lower spiral chamber of the second element, through which it passes from the center to the periphery. From here it proceeds to the lower chamber of the third element and so on until at last it makes its exit from the lower chamber of the upper

element. The steam to be condensed, entering above, takes the opposite course, running through the upper spiral chambers of each element in succession, giving off its heat to the cold water, through the thin copper plates (dividing the two chambers), until it issues as water below. The process of the steam's parting with its heat is further favored by the chamber's floors being traversed by ribs, which arrangement causes the steam, as well as the water, to be constantly stirred. It is stated by Busley[9] that the caloric effect of these condensors is almost from eight to nine times as great as that of the ordinary tubular surface condensors. Thus in a condensor of four plates and a cooling surface of 0.56 square meter, the hourly product per square meter surface, is the conversion of 270 kg. of steam of 116.290 C. into water of 13.60 C. in which is only 2.9 C. warmer than the water used for cooling purposes. (Figs. 3, 4 and 5.)

AERATION AND FILTRATION.

In some of the smaller gunboats and other naval vessels that are unprovided with the refrigeration plant and have but a small tank capacity, it often happens that the distilled water does not remain in the tanks long enough to get cool and the drinking water must be consumed while yet warm. This is especially often the case in tropical climates, just where a cool and refreshing drink of water is most gratefully appreciated. Under such conditions aërators are very desirable.

Figure 6 is intended to show an aërator constructed by Chief Engineer (now Captain) George H. Kearny, U. S. N., according to my ideas, and later, much improved by him installed on board the U. S. S. *Marblehead.* A small pump takes the water from the distiller to the top of the tower where the water drops in succession through a series of perforated copper discs, and, in this manner, becomes cool and aërated. At the bottom, the tower opened into a larger receptacle which served as a reservoir and from which the water was sent either into the tanks or into the scuttle-butt. This aërator did excellent work both as regards aëration and cooling. On board the *Yantic* the men spoke affectionately of their water tower, but my sudden detachment from the ship did not give me time to make the observations I

9. Busley, C.: Die gesundheitlichen Einrichtungen der modernen Dampfschiffe, Berlin, 1897.

had planned to. The illustration here shown lacks the double cylinder which was intended for the aërator to be installed on board the U. S. *Yantic.* There was to be an air chamber between the inner cylinder through which the water descended and the outer cylinder, to protect the water from the heat of the sun. The openings through which air was admitted to the tower were protected, moreover, by several layers of flannel to remove the dust from the entering air; this also is not shown in the figures.

How carelessly, in former times, some of these aërators were made and used is shown by an incident in my experience in 1890. Shortly after reporting for duty as medical officer of the U. S. S. *Yantic,* in 1890, the unusually large sick list and the nature of the complaints led me to examine the drinking water. This was found to contain organic matter and chlorids in large amounts. The commanding officer insisted that the water was distilled and could not be the cause of the illness. The trouble, however, was promptly traced to the aërator.

The aërator in use at that time consisted of a wooden box about 6 ft. long, 1½ ft. high on one side and ½ ft. wide. The box stood on deck with one of its sides against the engine room hatch; the distilled water entered at one end and passed out at the other, presumably cooled and aërated. When the men were washing the decks, which was done with salt water drawn up in buckets from over the side of the ship, dashing the salt water along the deck, large amounts of it were thrown into the aërator. When it was realized that the *Yantic* was at that time alongside the wharf in the navy yard of New York near the Simpson Dry Dock within 20 ft. of a large privy and urinal, not to speak of the sewers of Brooklyn, no more proof was needed. Suffice it to say that one demonstration of this kind convinced the commanding officer that this aërator was the efficient cause of both the bad water and the sick list and the antiquated piece of apparatus was abolished and the one, described above, put in.

Air injectors and carbon filters were at one time thought to be necessary parts of distillers. The air injectors were usually interposed between the evaporator and the condensor into which latter the air was introduced while the filter was placed between the con-

densor and the water tank. These injectors seem never to have made good their claims. With the latest distilling apparatus an oily taste in the water can be avoided and the filters of any kind do not seem to remove that taste when present; with our increased experience and knowledge of the means of distilling sea water in ships, even the carbon filter will probably soon be discarded altogether and pass out of use.

Figure 5 shows one of these filters of the very best pattern. Here the water enters above and, being at once deflected by the carbon plate over the loose pieces of carbon, is distributed through the outer chamber; from here it passes into the inner one and after traversing the inner chamber and the solid carbon block, it runs directly into the tank through the ordinary pipe connections, awaiting its further distribution to convenient places by small steam pumps. The Chamberland filter, after but a trip trial on board ship was given up as impracticable.

According to Plumert[10] the one filter possessing the greatest advantages and the least disadvantages for ship's use, is the micro-membrane filter of Kregor of Vienna. Such a filter is said to furnish 500 liters an hour. But the problem at present before us is to provide such a water by distillation on board ships that does not need to be filtered and, such a water can now be furnished with our present distillers when these are properly managed.

Thus, our experience with peripheral filtration on board ships has resulted similarly to that on shore. The observations of Hesse and Plagge, those of Woodhead and Wood and of Freudenreich and Schöfer have shown that peripheral filtration is, to say the least, not absolutely trustworthy. According to Frankland, Woodhead and others, it was shown that charcoal especially adds to, rather than detracts from, the number of germs after it has been used for some time. This is exactly the general experience with such filters on shipboard; and when the injectors had poured volumes of dust into them, such filters proved to be veritable culture media for germs. All these objections become, of course, accentuated in the tropics.

10. Dr. Arthur Plumert: Gesundheitspflege auf Kriegschiffen. 1900.

In a recent article by Le Méhauté,[11] that author wants the air injector to be abolished because of being both useless and dangerous; useless, because the water may be trusted to aërate itself; and dangerous, because the injected air introduces myriads of germs, the nature of which cannot be controlled, although granting that for the most part they consist of non-pathogenic saprophytes. Le Méhauté, moreover, deems the carbon filter superfluous. At one time, says he, it answered a purpose, namely, that of removing particles of lead and greasy matter. Now, since these dangers no longer exist, the filter has become unnecessary.

CHANGES IN OUR PRESENT METHOD OF STORING AND DISTRIBUTING WATER, RECENTLY PROPOSED.

Certain well-marked sanitary defects inherent in our present methods of storing and distributing water on shipboard must have been noticed by every thoughtful naval surgeon, no matter how brief his experience at sea. These defects concern the water tanks, the pipe connections and the scuttlebutt. To begin with, one fundamental difficulty about the water tanks, located as they are, near the bottom of the ship, is, that it is at times almost impossible for a man in the hold to distinguish the one containing merely feed or other utility water from the one containing distilled water for drinking. Since much might depend on this under certain circumstances, measures should be taken to prevent such a mistake from occurring. A radical remedy has recently been suggested by Couteaud and Girard,[12] who recommended the establishment of two separate holds, one in the forward part, the other in the after part of the ship; one for utility water, the other for distilled water. Again, the danger of drinking water becoming mixed with utility water on board ship is not alone dependent on a mistake in the tanks; it may likewise be traced to faulty pipe connections, as was shown in a recent experience of mine. In this instance, the drinking water, as well as the salt water, were circulating in one system of pipes, separated from one another only by certain cut-out valves. The consequence was that neither sweet water nor salt water could be drawn without taking part of the other into the bargain. Since

11. L'eau potable a bord. Arch. de Med. Navale, 1904, Nos. 9 and 10.
12. L'Hygiene dans la Marine de Guerre, Paris, 1905.

the quantity of salt water thus added to the sweet water in both kitchen and pantry was very large; and since, moreover, the salt water, in this instance, was in fact undiluted sewage drawn from the harbor of one of our navy yards, it could not help being quickly discovered and remedied. One such experience ought to suffice to show the great necessity for the widest possible separation of both tank and pipes carrying utility water from those carrying distilled water. Each should circulate in its own separate system of pipes and be independent of cut-out valves.

Dr. Le Méhauté, in the article referred to above, has placed the whole subject in an entirely new light before the naval medical profession. He has clearly pointed out present defects and suggested means to remove them. The objects to be aimed at are: (1) The protection of the water from impurities that may originate in the present reservoirs and pipes themselves; (2) its protection from the impurities liable to get into it from the outside; (3) the providing of a method for the disinfection of tanks and pipes.

The measures which Le Méhauté suggests to meet these various demands are as follows: (1) Simplify the pipe system and remove all unnecessary parts of it; (2) hermetically seal the entire system and make the water circulate in a closed system of vessels; (3) protect the metallic sides of the system against attacks by water; (4) provide a method to disinfect the system which shall be simple, efficacious and always at hand; (5) adopt steam under pressure as a means for disinfecting the pipes.

It certainly would seem obvious that by reducing the length of the distributing pipes and by removing all unnecessary parts of the system the danger from inside impurities can be materially decreased. Since, perhaps, the greatest danger from impurities lies outside the system, the hermetic sealing of the entire system, from the tanks to the fountains, would almost suggest itself. The dangers lurking around the water tanks from outside contaminations must have suggested themselves to every inspecting officer who has seen them and appreciated them but once. The changes recommended by Le Méhauté as regards the construction of these tanks, in view of these dangers, would seem to be most opportune and very much to the point. They are: (1) Place the

manholes on the side instead of at the top of the tanks; (2) provide every tank with a metallic aspirating tube permanently fixed to one of its sides and closed outside by a screw plug; (3) ventilate the tanks through an ┐ shaped pipe, provided at the lower outside end with a tampon of absorbent cotton to filter the air; (4) keep the upper surface free, closed and unencumbered; (5) slightly incline the bottom surface to allow of the accumulation of any deposit of possible iron rust and provide a purging spigot at the most dependent part of the bottom of the tank for an easy removal of the solid impurities collected there. Another suggestion deserving attention in this connection is the one made by Couteaud and Girard.[13] These authors would reduce the large number of small tanks, at present in use, into a small number—say three or four—of large reservoirs or cisterns, containing up to 14 or 15 tons of water each and place them between the two protective decks. They are also in favor of placing the manhole on the side instead of on top.

These suggestions are sound, and every naval sanitarian will endorse them without much hesitation. The hermetic sealing of the pipe system would naturally make disinfection sometime a necessity and hence provision must be made for it. Since it would involve a great deal of difficulty to take the system apart for such a purpose, the method of steam disinfection suggested is the one practically applicable method. For the purpose of disinfecting the tanks, the soldering lamp is no doubt the best means. Whether it is that the pipes are choked up mechanically with iron rust or coal dust, or. whether infected water has passed through them. the method of steam disinfection is equally applicable.

Thus, it will be seen, that hygiene has become exacting. It cannot rest content with half-way measures because these do not meet her ends. It is due to half-way measures that some much useless time and money-wasting experimenting has been done in the past, as we have seen, without producing the desired results. It is also evident that the hermetic sealing of the whole water circulating system and the modifications in the construction of the tanks, as recommended by Le Méhauté, must insure a faultless product inside of them.

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13. L'Hygiene dans la Marine de Guerre, Paris, 1905.

Having thus far obtained a perfect water inside of our tanks and pipes, we must aim to get it inside the sailors' stomachs in the same uncontaminated condition. To this end, the scuttlebutt system is the next detail to be improved.

DISTRIBUTION OF WATER.

The problem involved in the process of conducting drinking water from the tanks to the individual in an absolutely pure and uncontaminated condition has never until recently been approached courageously and seriously. It is held by some that the greatest and gravest danger lies in the manner of distributing water on board ships; that infectious diseases are more often transmitted and epidemics spread and kept alive through the common drinking cup than in other ways. Even the individual drinking cup appears to have proved a failure and has been abandoned where it was used formerly, because, if the men did not lose it, they would loan it to one another and thus defeat its very object.

To-day, men in most of our ships get their drinking water from what is called the "scuttlebutt." This is a wooden barrel-shaped vessel, somewhat broader below than above, provided with a brass spiggot near the bottom and varying in size with the size of the ship and in number with the number of men on board. On large ships several of these are placed in convenient places. A common drinking cup of some metal is attached to the spigot by a small chain and this the men use to get their water. At one time the interior of the scuttlebutt was divided into an upper containing carbon, spongy iron, etc., and a lower compartment containing filtered water. At one time, a long stationary metallic tube was inserted, the lower end being immersed in the water, the upper bent into a right angle and terminating in a mouthpiece through which the men were obliged to suck up their water. This method was in general use in the French navy from 1819 to 1850, when the order was passed for mouthpieces to be made of glass; these breaking too easily, the mouthpieces were ordered to be made of iron, of lead and still others of wood. None of these ever proved entirely satisfactory. In 1869 Lefèvre says of the custom of using the mouthpieces, then in general use: "Besides the repugnance which such a method must inspire of being obliged to

take into your mouth a nozzle which was a moment before in that of another, does not this practice open the way for the transmission of contagious diseases from one man to another?" And indeed Fonessagrives had already then recommended that these mouthpieces be made detachable and that they be immersed in water before being used. Bressanin likewise recommended immersion in water. Others recommended a detachable mouthpiece, one that could be increased in the suction pipe of the scuttlebutt and was attached to each person by a cord so as to prevent the wearer from either leaving it attached to the mouthpiece or losing it, or even lending it to another. According to Couteaud and Girard, the scuttlebutt in use in France is made of iron, lined with rubber; it has a spiggot to which the common metallic drinking cup is attached with a chain. They recommended the substitution of a *biberon a bec* for the cup. These *becs,* after being used, to be put into a basin where a jet of hot water may disinfect them. The particular mouthpiece they refer to is made of iron and was designed by chief mechanic Estève of the *Iena.* According to Belli,[14] Dr. Carbone has actually succeeded in getting the individual cannula adopted on board the *Pisani.* On this ship every man is provided with a mouthpiece of bone which he attaches to the scuttlebutt whenever he wishes to quench his thirst. An arrangement of three small elevations around the opening of the pipe at the scuttlebutt obliges the man to use his own mouthpiece to get water. While Belli is convinced that this method is theoretically a good one, in practice, it has shown to have several disadvantages.

The cannulas become clogged easily from dirt in the pockets of the men; they also can be passed from one to another, just as the individual drinking cup. Belli raised the question as to the necessity of all men being obliged to get their water by suction. Indeed, since the necessity for so great an economy, as was practiced in former years, on long voyages, has entirely made way for a more liberal distribution of water, this question is very much in order. Belli wants these suction arrangements abolished and thrown on the scrap heap. In the U. S. Navy this arrangement has never been popular, but the common drinking cup is in general use.

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14. M'Belli, Innovazioni igieniche sulle nave da guerra—ann. di mod. navale. Annovifasc, vol. III, 1900.

Within recent years, water fountains have been recommended for use on board ship to take the place of the old scuttlebutt. Since, with these fountains alone, the question of the common or individual drinking cups remains the same, only special fountains can come up for consideration. The need for a hygienic distribution of water on board ship is very much the same as it is in the case of public schools and other public places. In 1894

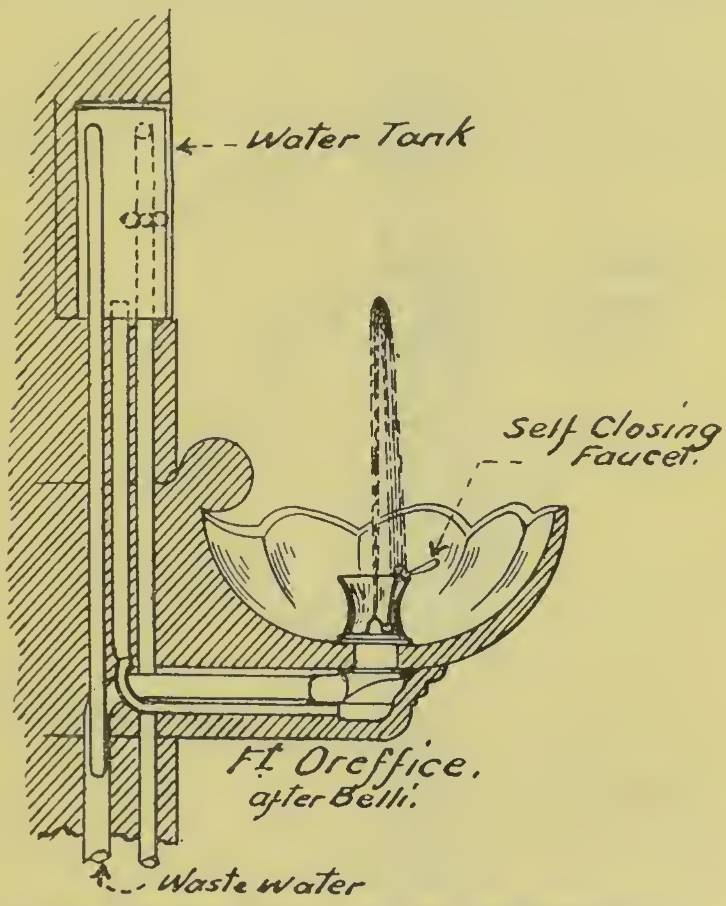


Fig. 7.—Showing water tank and self-closing faucet.

an Italian engineer named Torelli exhibited a fountain at the National Exposition at Milan. This fountain is in actual use in the public schools of Milan. It consists of several little spouts fed by water under pressure and arranged in a circle inside of a basin. Each orifice is protected by a funnel, 15 cm. in height, perforated at the bottom and not permitting the drinker to touch the orifice with his mouth or with his fingers. In drinking the boys simply lean over the spout and allow the water

to flow into their mouths. A similar fountain has been constructed by Dr. F. Accorimboni for the normal schools at Foligno in which the jet projects horizontally (Fig. 8) and in which the nozzle is protected from contact with the drinker's lips by a metallic screen.

The fountains of Milan and of Foligno, however, are without a regulator and the water flows constantly. Such a regulator is found on the fountains designed by the engineer, Oreffice, and introduced by him into all

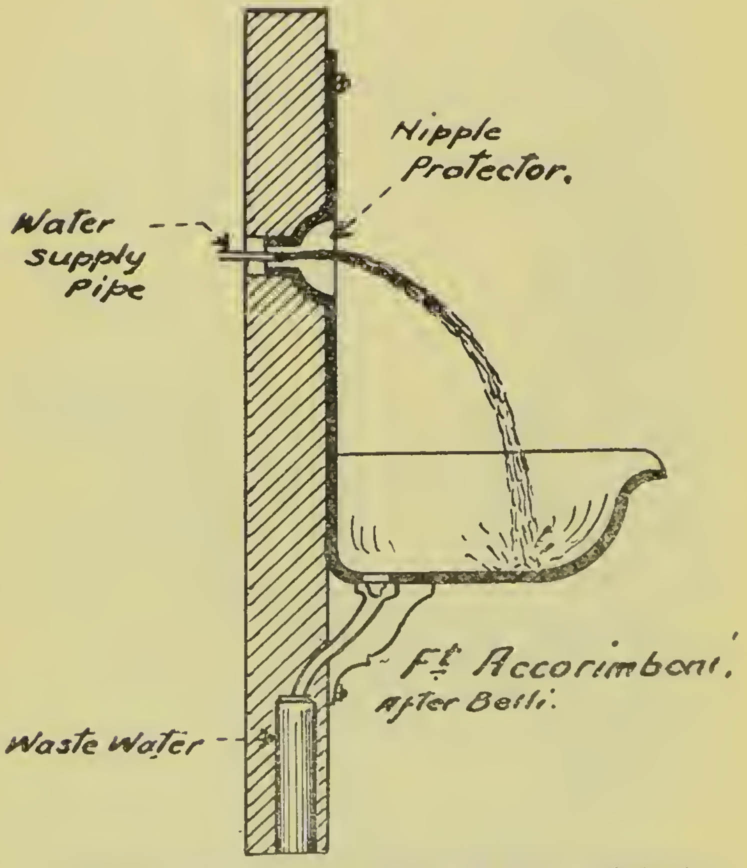


Fig. 8.—Drinking fountain designed by Accorimboni.

the public schools of Padova and Venice (Figs. 7 and 9). The little jet is provided with a spring lock which the drinker opens at will and which closes automatically, thus avoiding unnecessary waste of water. The little short orifice is protected by a conical cup, the upper margin of which is armed with a metallic fringe which does not permit the drinker to approach it with his lips. The slight overflow rinses the walls of the cup and passes directly into the waste pipe.

Belli suggests that the advantages of these two fountains combined might, perhaps, be adapted to ship's use. A proper combination, no doubt, would do away with the risk of infection and at the same time insure the economical use of drinking water.

It certainly has become highly desirable that the old-fashioned scuttlebutt with the common drinking cup as now in common use in the navy be displaced by some form of reservoir of distribution, answering to the present requirements of personal hygiene. Since it has become recognized beyond question that the common drinking cup is one of the worst means of spreading contagious diseases on board ship, efforts are now being

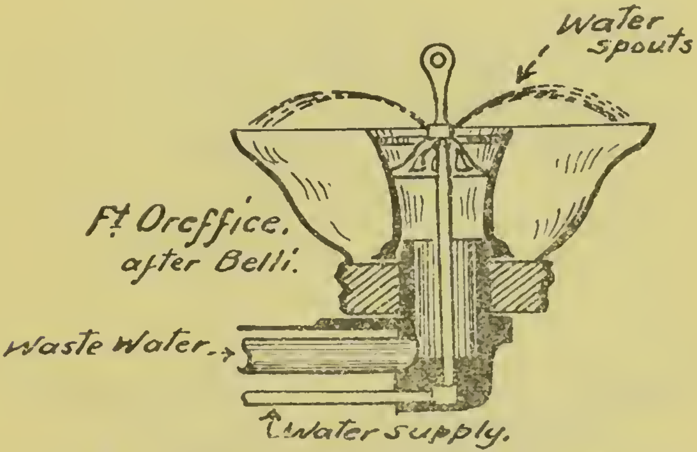


Fig. 9.—Drinking fountaain designed by Orrefice.

made in almost all the navies of the civilized world to do away with it.

Le Méhauté is very strongly in favor of the individual pipette. The fountain which he prefers is shown in the adjoining Figure 10, which shows the pipettes in place. He proposes that a number of these pipettes, duly sterilized, be placed in a vessel near the fountain where any man may take one, put it in place, drink and then put it into another vessel, where it remains until again sterilized by boiling in soda.

DISTILLED OR STERILIZED WATER.

An important sanitary question has only recently been raised by Le Méhauté[15] of the French navy. The question asked by Dr. Le Méhauté is whether it shall be

15. Arch. de Medicine Navale, Nos. 9 and 10, 1904.

distilled or sterilized water that is used on vessels of the navy or whether both be used under a given set of circumstances and conditions. This question is important and destined to receive considerable attention by naval sanitarians in the near future.

It is, of course, of fundamental importance to hygiene to furnish such a water as shall in composition correspond as nearly as possible to a natural, unpolluted

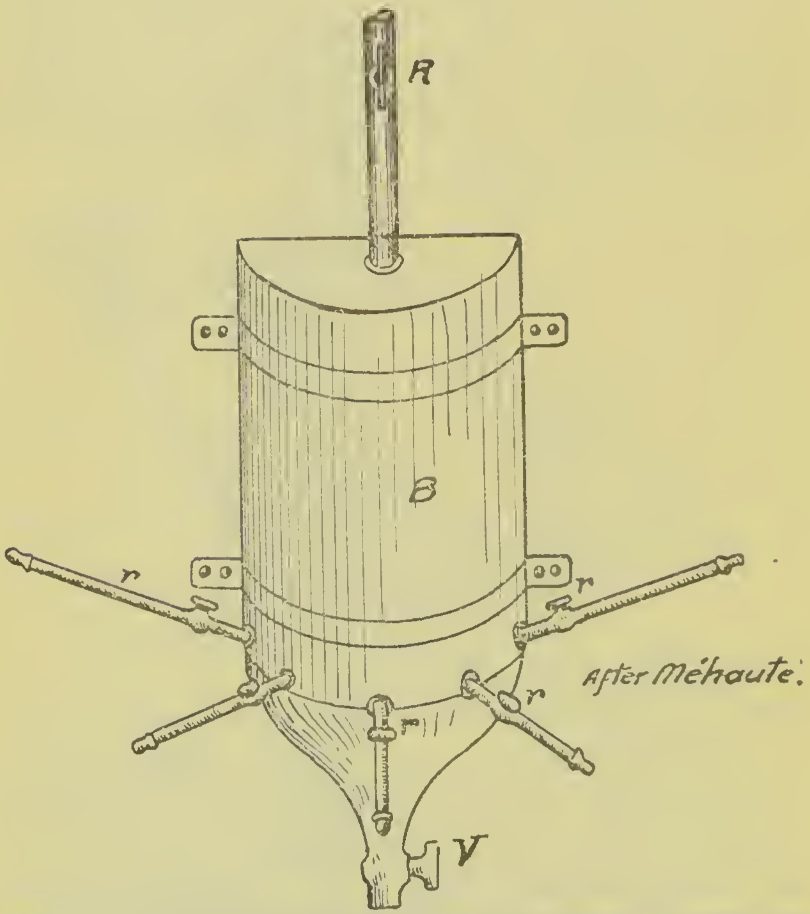
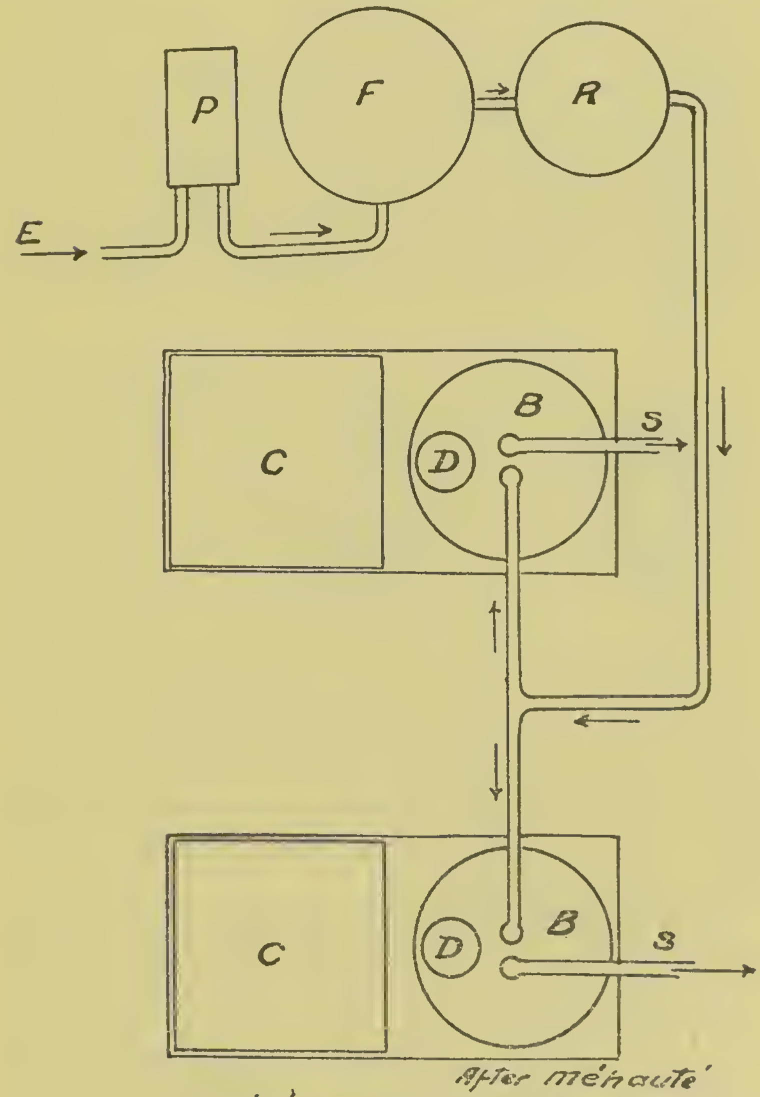


Fig. 10.—Drinking fountain favored by Méhauté, showing the pipettes in place.

drinking water. There is no longer any doubt about the fact that distilled water for ship's use is no such absolute necessity as it was in years gone by. Since the wooden casks have been generally done away with and a cement lining for iron tanks was adopted, water put into them no longer putrefies, but keeps sweet for an almost indefinite length of time. Most of the large passenger steamers have, for many years past, taken

their water supply directly from the water mains of the port in which they happened to be and filled their tanks and double bottoms with it. Steamers rarely resort to distillation, though legally obliged to carry dis-



Ship's Water Sterilizer.

Fig. 11.—Showing the principles of the sterilizer which Méhauté proposes for adoption. P, water reservoir; F, pressure filter; B, where hot water gives off heat to incoming cold water; C, the heater; D, apparatus where precipitates are removed; E, where water enters; S, where sterilized water makes its exit.

tillers on board, on account of the short duration of the voyages they make. Although vessels of war invariably carry distillers, they, too, fill up with sweet

water before leaving port and distill only on long voyages and after their sweet water supply has begun to give out.

It must be admitted, perhaps, that a sterilized water is more nearly a natural water than is distilled water and as such deserves the preference. The general desire on the part of all civilized governments at present is becoming more and more evident, namely, to make every effort to surround their men-at-arms, whether ashore or afloat, with the most sanitary conditions possible. Already the French war department has begun to introduce water sterilizers in large numbers into the soldiers' barracks, and naval stations are being supplied with them. Le Méhauté strongly urges the introduction of sterilizers into the navy, arguing as follows: "Certain vessels of the navy are destined to remain for a long time on foreign stations and others are obliged to make long cruises, visiting places in which the supply of water is not always good. For such ships distilled water is a necessity. Many other ships, however, stay on the home station or visit places in which the water supply leaves nothing to be desired and where, consequently, these ships may supply themselves with all the water they need. Such water, to eliminate the last possible chance of doubt, need only be sterilized." Méhauté, moreover, says of sterilized water that it bears the same relation to distilled water as does natural food to unnatural or canned food and that it would be both unwise, uneconomical and unhygienic to drink distilled water or to eat canned food when the more natural products were available.

The principal reasons for substituting sterilized for distilled water, in which we must all agree, are three: (1) Distilled water is expensive and sterilized water is not. (2) Distilled water is not a natural water; sterilized water answers more nearly to that description than does distilled water and should, therefore get the preference. (3) Distilled water is often offensive; sterilized water is never offensive and always safe, being germ free. Certain objections have, however, been raised against the introduction of sterilizers by Couteaud and Girard,[12] the principal ones of which are the following: (1) The inconvenience of having on board two systems of water purification, since distilling can not be done away with and must remain the last resource; (2) the steril-

izers have not worked well either in France or China, where they were used during the campaign of 1900-1901, on account of the hard Chinese waters (Jacquemin). It is also not inconceivable that the different parts attached to the sterilizer might become sources of infection.

According to Le Méhauté, the sterilizer Salvator can be made to produce one ton of water at 7 centimes in French money. Professor Vaillard, at Val de Grace, has calculated that two kg. of coal furnished 2,000 liters of sterilized water, while the quantity of distilled water cost 7 francs the ton. According to Couteaud and Girard, Chief Engineer Danoy has made some calculations on the Iena that would not seem quite so favor-

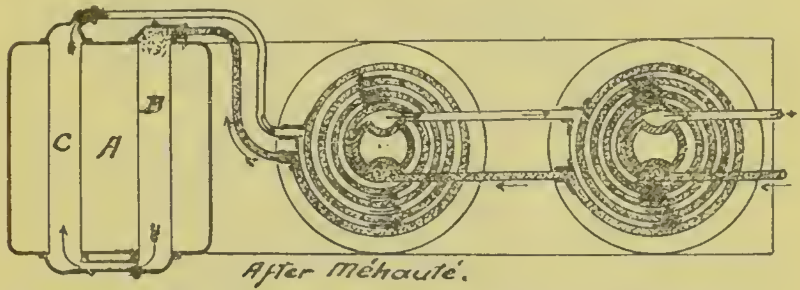


Fig. 12.—This represents schematically the circulation of the water in the recuperator.

able. He calculates that one kg. of coal burned in the furnace would sterilize $\frac{5176 \text{ cal.}}{170 \text{ cal.}} = 30$ kg. of water. This same kg. of coal would produce 5 kg. of distilled water; that is, 1/6 the quantity of sterilized water. The actual daily expenditure in sweet water on board the ship was 9,000 liters, of which 800 liters were distilled water used for drinking. These last cost the state $\frac{800}{5} = 160$ kg. of coal. If it was necessary to sterilize all the 9,000 liters of sweet water, the cost in coal would amount to $\frac{9000}{5 \times 6} = 333$ kg., or just twice the amount required to distill the 800 liters of drinking water.

The adjoining diagram (Fig. 11) is intended to show the principles of the sterilizer which Le Méhauté proposes for adoption. In this scheme P represents the water reservoir, F the pressure filter, R the accumulator, B where the hot water gives off its heat to the incoming cold water, C is the heater, D is an apparatus in which

the precipitates are removed, E shows where the watei enters, and S where the sterilized water makes its exit.

Providing a double sterilizer is installed, each one

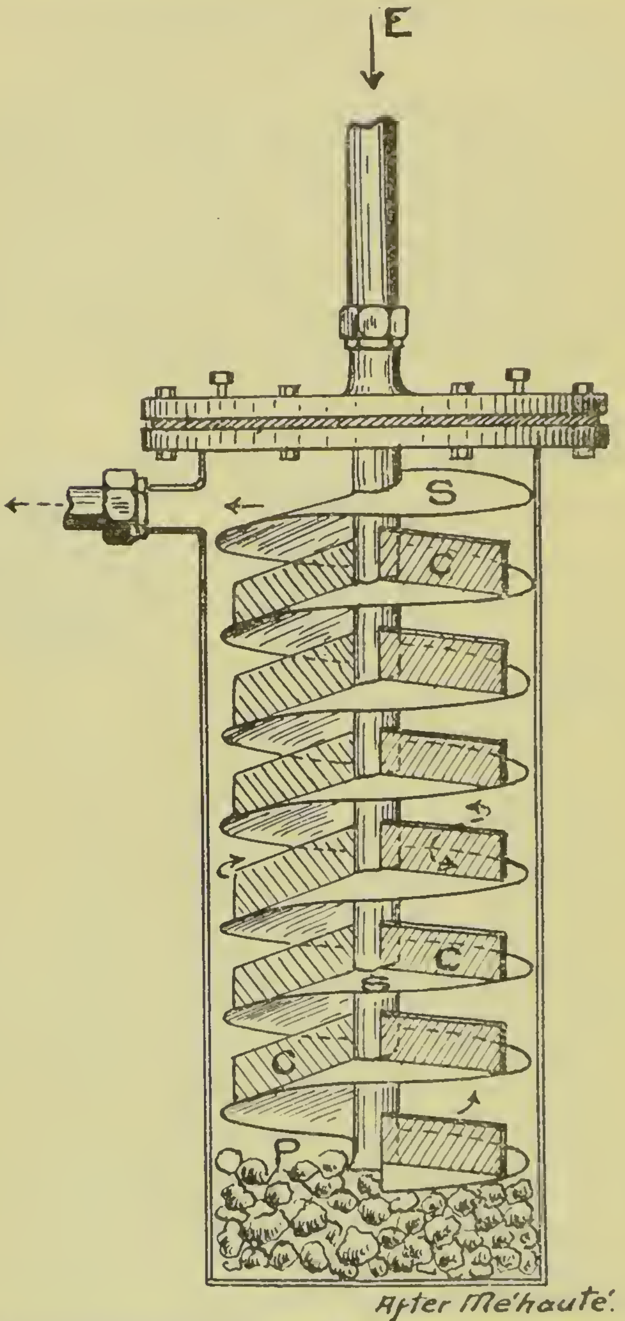


Fig. 13.—Apparatus for removing precipitates from hard water.

working independently of the other, no check in the process need be apprehended. The heat required for

sterilizing comes in the form of steam from one of the main boilers.

The only part of this sterilizer needing special description is the recuperator (B), in which the sterilized hot water parts with its heat, transporting it to the incoming current of cold water. This piece of apparatus it is intended for the adjoining diagram to illustrate and make intelligent.

Figure 12 represents schematically the circulation of the water in the recuperator. The white spiral shows the course which the water takes that is cold and to be sterilized; the shaded spiral contains the warm sterilized product. In order to give back to the sterilized water its refreshing taste, a very ingenious apparatus has been employed.

This apparatus is made of spirally arranged metallic plates, inclosing spaces about 26 cm. high and 5 mm. broad and absolutely tight. These spaces are divided into two separate and distinct channels: The one for the cold and the other for the hot water. The cold water takes the direction toward the heater, the sterilized water passes on the inverse sense; the one goes from the periphery to the center, the other from the center to the periphery. In this circuit the heat is exchanged. When the sterilizer Salvator was tried on board the *Caledonian* and the *Couronne* it did not give entire satisfaction. Preliminary trials demonstrated the necessity of a filter and an attachment in some form for the removal of the precipitates formed during the boiling of an especially hard water. Both these desiderata having been met, the sterilizer works without a fault.

The more interesting part of these two additional pieces being the "detartarizor," a brief description will be of interest.

This apparatus (Fig. 13) is intended to remove the earthy precipitates from hard water that formed during boiling. The water enters at E, passes through the central tube to the bottom of the apparatus, where it enters a pile of rough stones, it then gradually rises along the spiral S which carries the vertical plates C intended to retard its progress, and thus compelling it to leave its suspended solid particles behind. The cleaning of the apparatus is very simple. It suffices to remove the cover, to take out the screw-like central part and clean it with a solution of HCL in water, 1/50.

With these two improvements attached, the French ministry of marine has made new trials which have proved unusually satisfactory, according to Le Méhauté, and the report made to him by Dr. Plagneux, the medical director at the depot at Cherbourg. According to these, the sterilizer has worked already for six months without needing any cleaning.

The preceding summary of the water question on board ships contains all the more important features of hygienic interest to-day. The proposed substitution of sterilized for distilled water may seem new to some of us, but it is a question which can not be evaded and which must be answered squarely in the near future.

With such a system as has been proposed by Le Méhauté, we might even question altogether the necessity of sterilization, except perhaps when the water in the tanks or in the pipes or fountains had from some cause been subject to infection or was under suspicion of being infected. With tanks lined with cement, closed on top and connected with a closed and clean system of pipes, pouring their water into a fountain provided with individual and sterilized pipettes, the chances of any possible infection of the water, as well as its transmission from man to man, seems infinitesimal and reduced to a negligible minimum. It is, however, just this negligible minimum which an exacting and consistent hygienist must try to eliminate.

There is no subject within the whole range of naval hygiene in regard to which the prospects for the near future appear as bright and as promising; none concerning which we are as near a satisfactory solution as with the water question on shipboard. At the same time there is no other problem the study of which would lend itself so well for illustrating the slow but sure and progressive influence of hygiene and sanitation on human affairs, near and remote, as does the story of the gradual evolution of the water question on shipboard from the earliest to the present time.